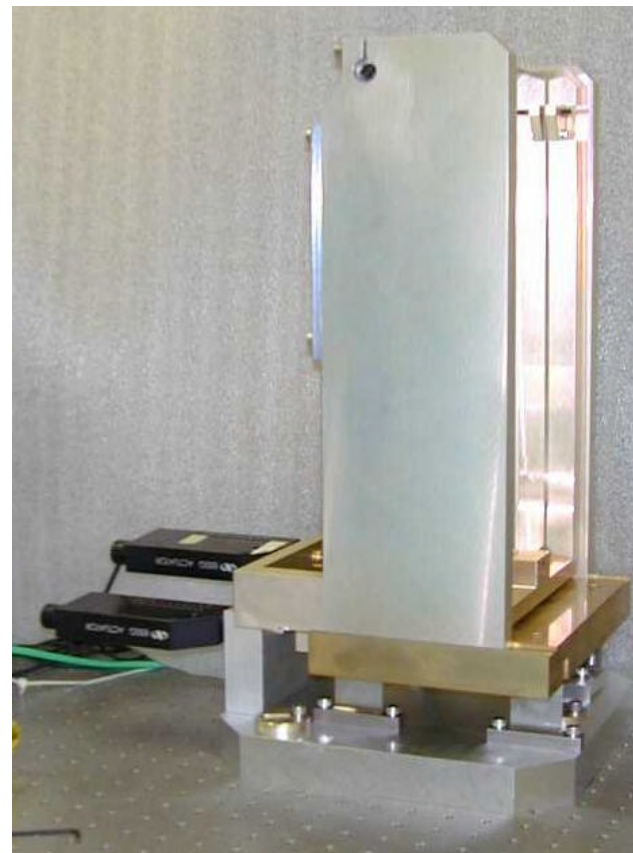


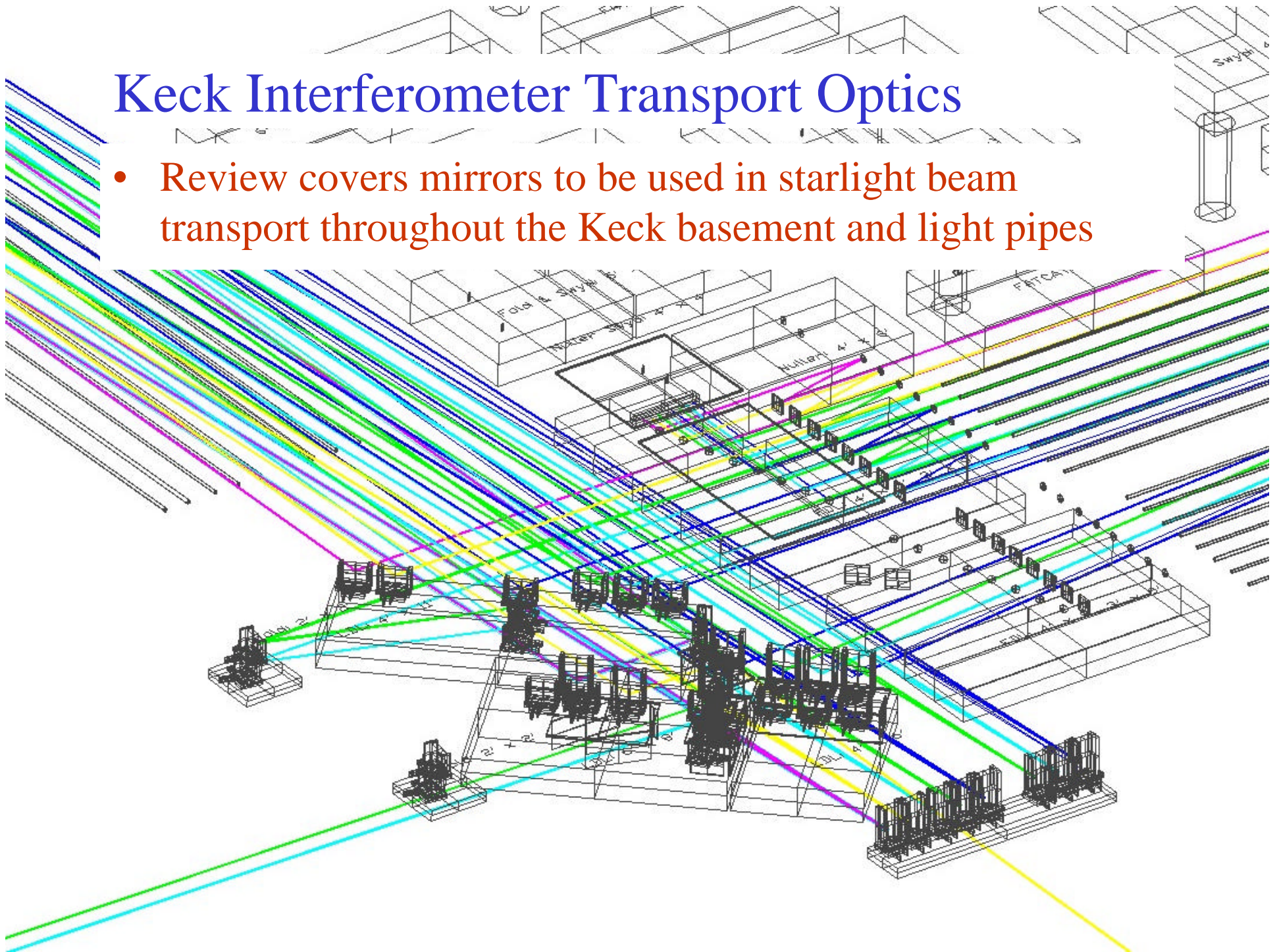
# Keck Interferometer Transport Optics Readiness Review Part 1 - Optomechanical

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Jim Moore, Len Reder,  
Robert Smythe



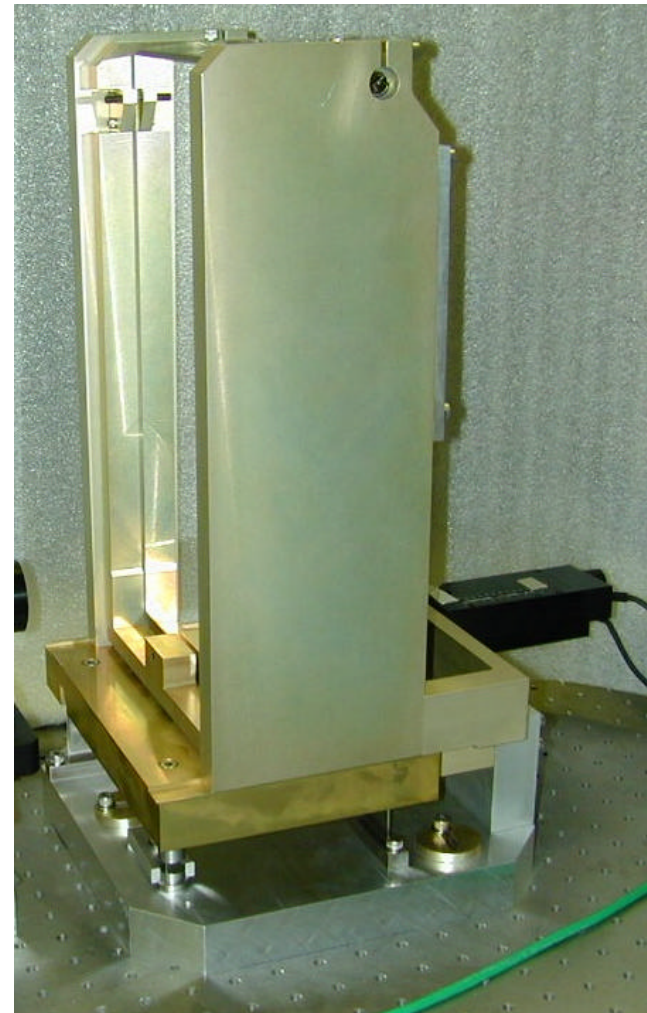
# Keck Interferometer Transport Optics

- Review covers mirrors to be used in starlight beam transport throughout the Keck basement and light pipes



## Mount Design Philosophy

- Common mode transport where ever possible for primary, secondary beam
  - Two 6” clear apertures on a single mirror surface
- Custom mounts to satisfy requirements of:
  - Custom mirror size
  - Minimum footprint
  - Minimum form factor
  - Pointing accuracy range



# Implementation

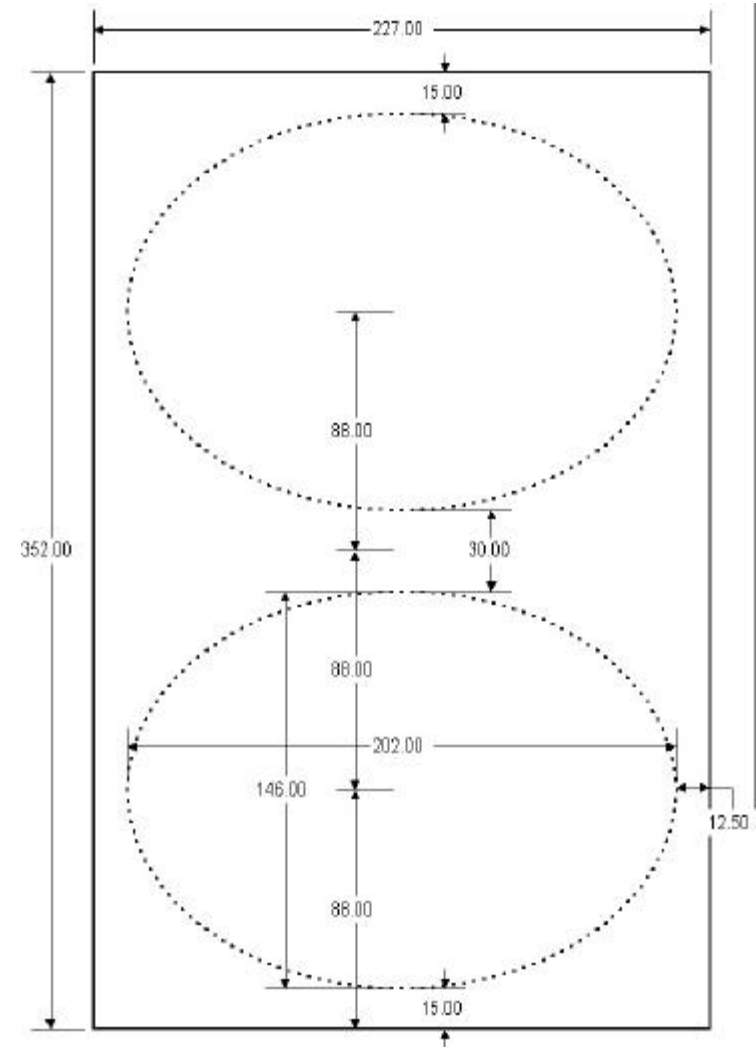
- Flexure mount
  - Smooth
  - Repeatable w/o backlash in flexure
  - Unlimited lifetime within design range
- 850G derived actuators
  - COTS part
  - Already in widespread use at Keck

## Acceptance Criteria

- Range of motion (physical)
  - 10 arcmin in azimuth
  - 2° in altitude (for LDL TOs, otherwise 20 arcmin in altitude)
- Incremental moves
  - 1 arcsecond
- Surface quality
  - $\lambda/20$  p-v surface at  $\lambda=633\text{nm}$  for mounted optics
- Mirror coating
  - Denton FSS-99 protected silver

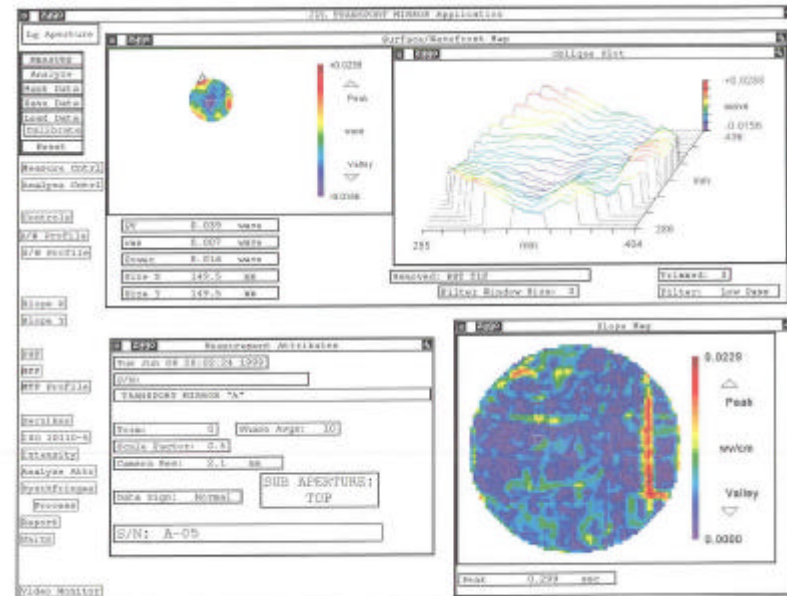
## Mirror Sizes

- Size A: 352mm x 161mm
  - Two 146mm beams at near-normal incidence
- Size B: 352mm x 227mm
  - Two 146mm beams at 45°
- Size C: 176mm x 227mm
  - Single 146mm beam at 45°

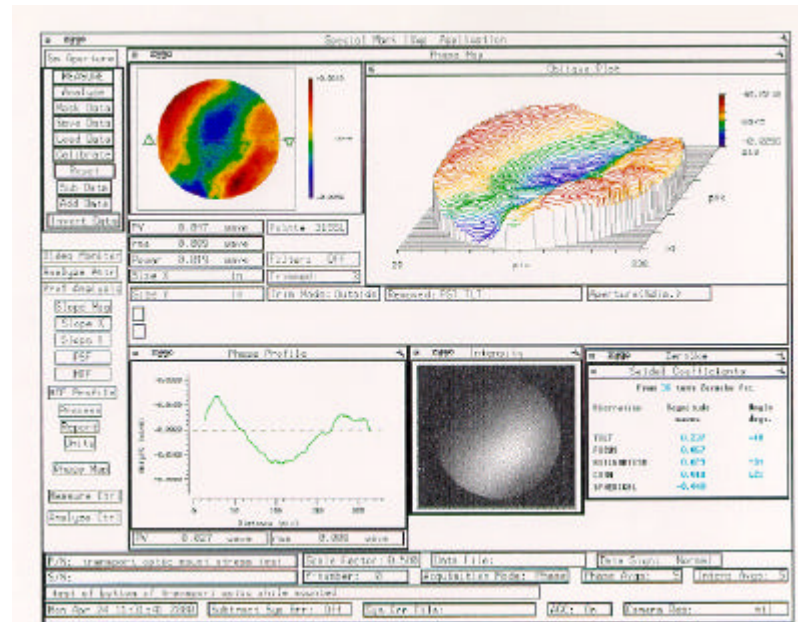


# Surface Quality

- Unmounted optics
  - Zygo delivered  $\lambda/20$  p-v surface at  $\lambda=633\text{nm}$  for unmounted optics



- Mounted optics
  - Measured in lab with Zygo PSI
  - $\lambda/20$  specification maintained in mount

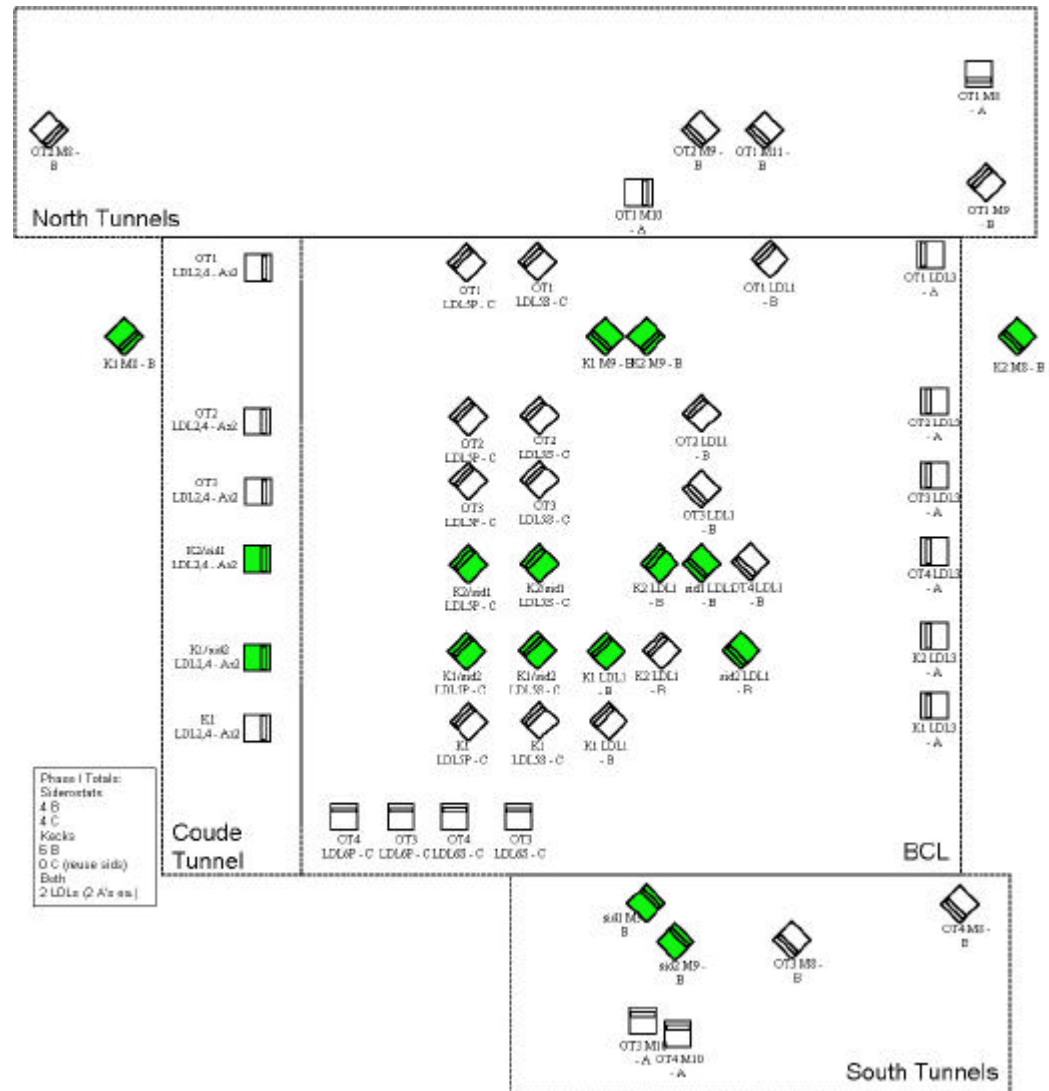


# Inventory

- Phasing plan written up and posted to docushare
  - Phase 1: Siderostat, Keck beamtrains, JPL lab
  - Phase 2: OT1, OT2
  - Phase 3: OT3, OT4
  - Phase 4 (tentative): OT5, OT6
- Totals (Mounts / Mirrors) - Phases 1-3
  - Size A: 10 / 22
    - LDL mirrors included in phasing plan
    - 12 A mirrors needed for 6 LDLs
  - Size B: 18 / 18
  - Size C: 16 / 16

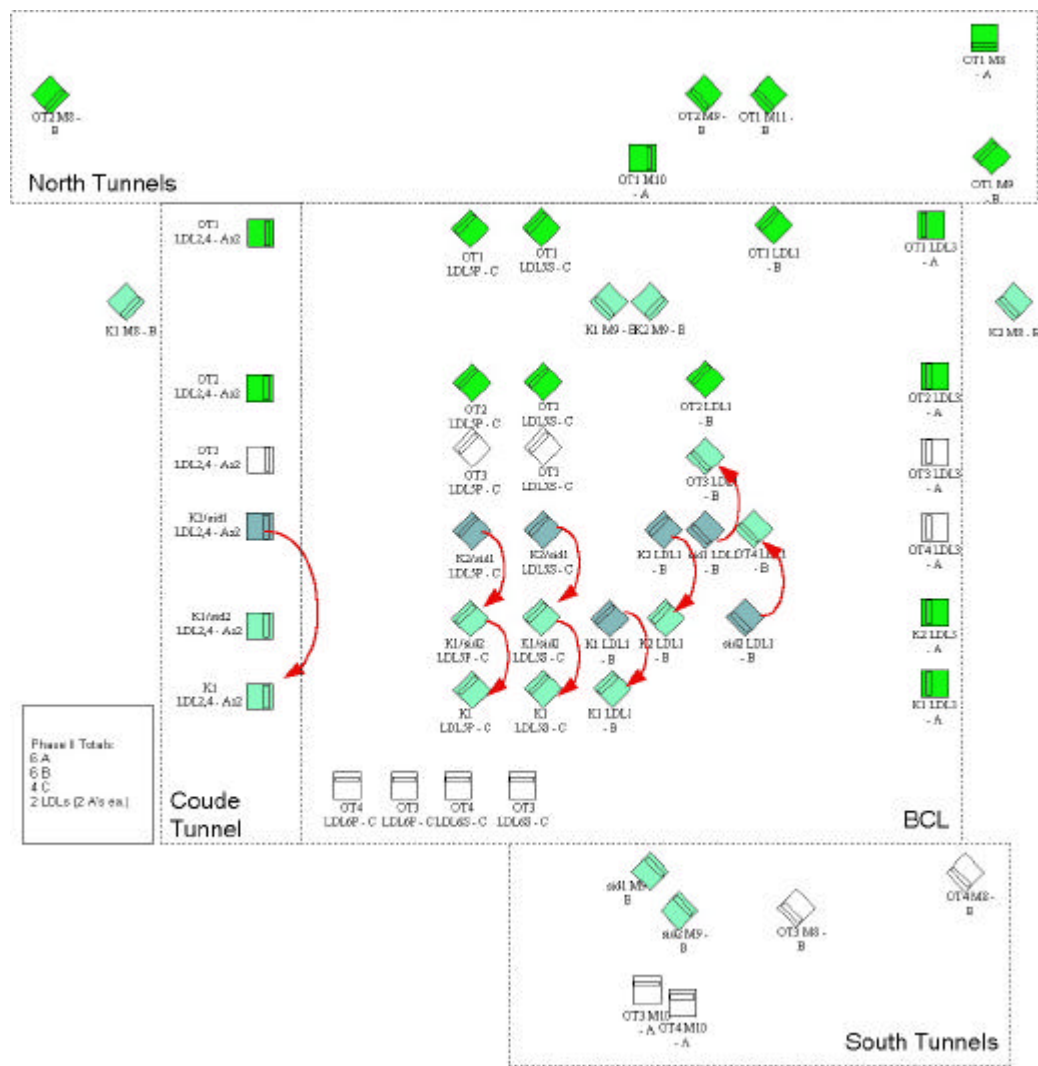
# Inventory: Phase 1 Install

- LDL tracks 2 & 3 populated
  - Fed by either K1/K2 or Sid1/Sid2
  - Minimizes LDL sled quantity
- Minimum install
  - No LDL double pass mirrors
  - No sid beamtrain switchbacks
- Totals
  - Size A: 0 / 4
    - 2 LDLs
  - Size B: 10
  - Size C: 4



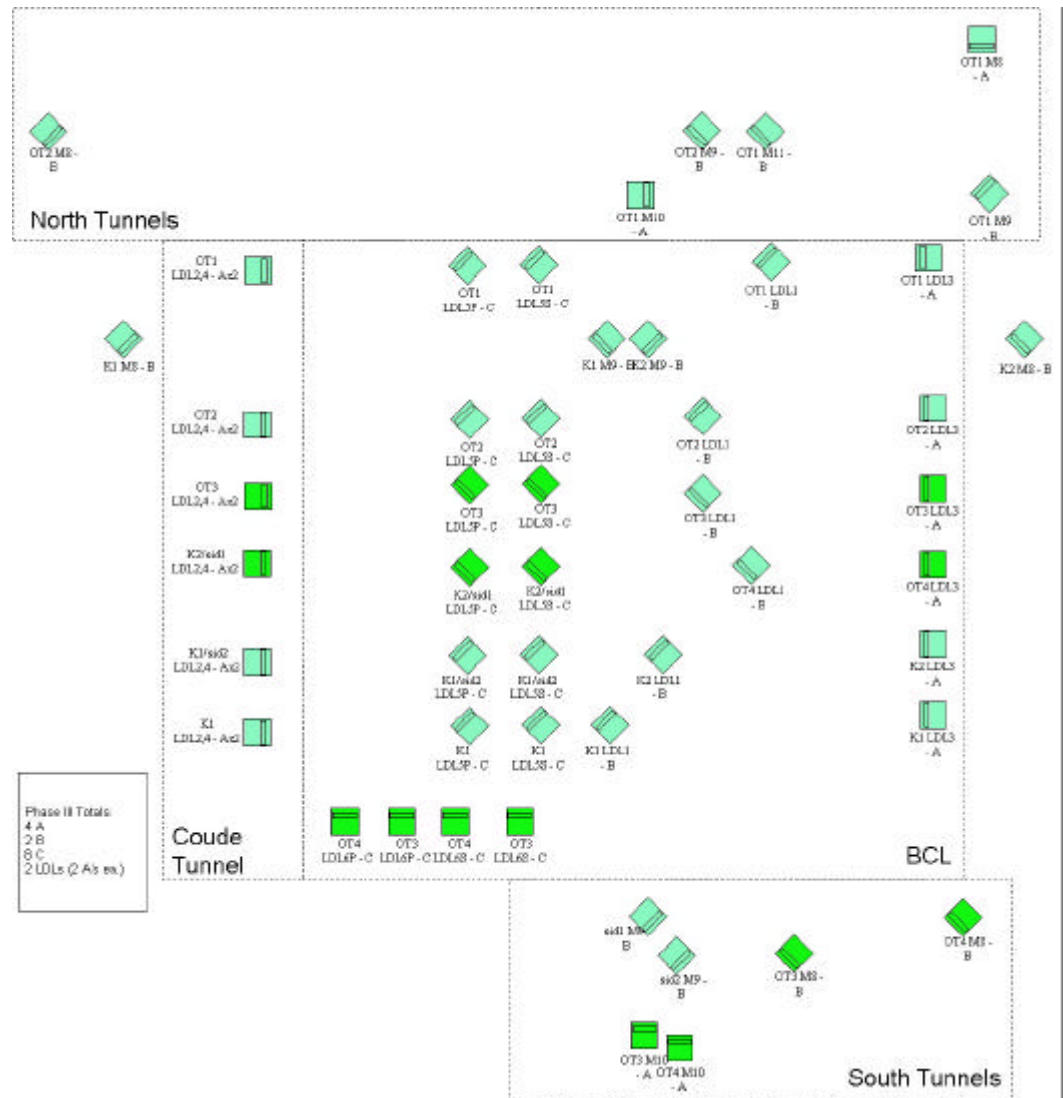
# Inventory: Phase 2 Install

- OT1, OT2 beam trains fully installed
- Full LDL build
  - LDL double pass mirrors installed for 4 DLs
- Shift of Kecks to dedicated LDLs
- Totals
  - Size A: 6 / 10
    - 2 LDLs
  - Size B: 6
  - Size C: 4



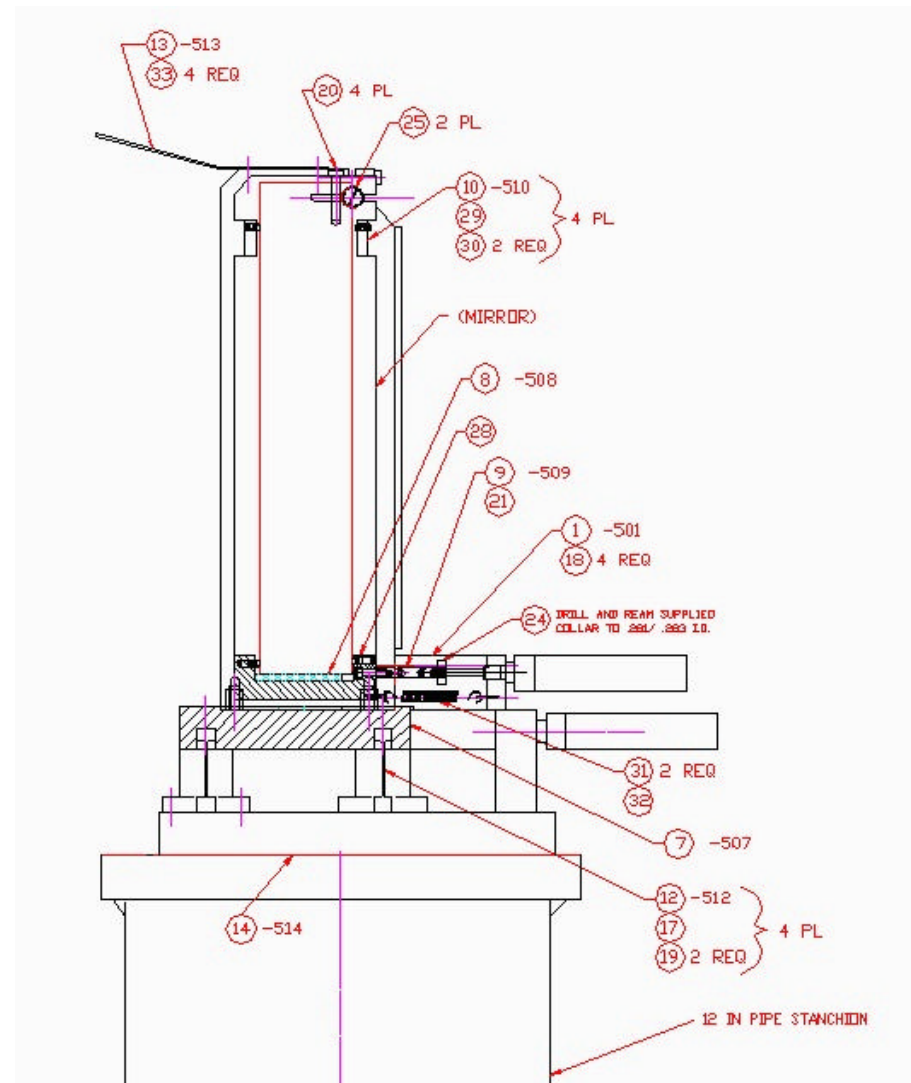
# Inventory: Phase 3 Install

- Large number of size C mirrors to accomodate OT3, OT4 switchbacks
- Totals
  - Size A: 4 / 8
    - 2 LDLs
  - Size B: 2
  - Size C: 8



# Mechanical Drawings

- JPL fabrication drawings have been ballooned, posted to docushare
  - All three mount sizes covered
- Parts list posted as well
- Final drawings to CARA by 6/30



## Data Sheets

- Data sheets posted to docushare for C-Flex and Lucas models (functionally identical)
- All other items listed on parts list, obtainable from McMaster-Carr



# Optics Ordering Information

- To date, two purchases of optics conducted
  - Round 1: Jan 99
    - Bids solicited from Nu-Tek, Kodak, Zygo, Sydor
    - Zygo had best offer for price & schedule
    - JPL handled purchase
  - Round 2: Nov 99
    - Bid solicited from Zygo only
    - CARA handling purchase
- Full packets for both rounds of procurement posted to docushare, including:
  - Cover letters
  - Specifications
  - Scanned copies of bids

# Mount Assembly. I

- Full assembly checklist written up, posted to docushare
- Illustrated assembly notes posted online as well



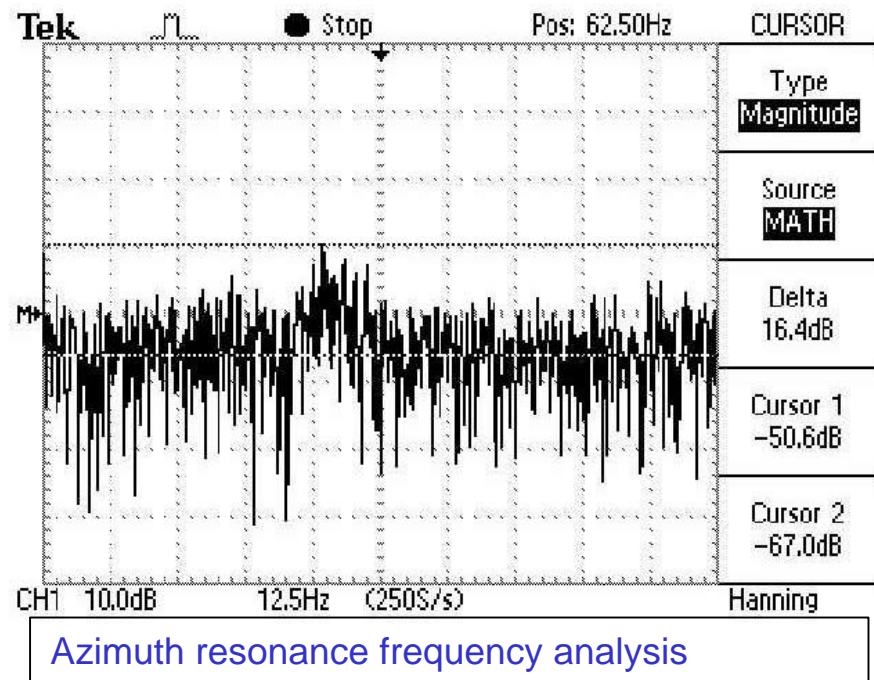
#	Step	Notes
1	assemble Transport Optic (TO) mount mechanical ass'y	to be done by mfr prior to shipping
2	assemble Transport Optic (TO) mirror holder mechanical ass'y	to be done by mfr prior to shipping
3	attach azimuth 850G	to motor mount -416; pushes against lever -406 preset in lab?
4	set az 850G limits(?)	
5	set az 850G to middle of range	
6	set mirror holder inside of the mount ass'y	to be done by mfr prior to shipping?
7	insert flex pivots	correct orientation needed; to be done by mfr prior to shipping?
8	attach altitude 850G	to motor mount -401; tilt flexure -409 attaches to end
9	set alt 850G limits to full range	
10	set alt 850G to middle of range	
11	clamp flex pivots to mount	use 1/4-20x1.25" with washer; verify flex pivot air gaps on sides and top
12	clamp flex pivots to mirror holder	verify flex pivot air gaps on sides and top
13	run soft tip set screws all the way back	
14	remove all 4 mirror stops -410	
15	insert mirror	use a tilting motion; take care to not scrape the mirror against the front stop in the mirror holder base -408 set extension of soft tip set screws to 9/32"
16	re-mount the two rear mirror stops -410	
17	slide the mirror back to just touch the soft tip set screws	
18	re-mount the two front mirror stops -410	run the soft tip set screws to just touch the mirror face
19	torque the back side soft tip set screws to a torque of 35 in-oz	

## Mount Assembly. II

- Specifics covered in writeup
  - Insertion of flex-pivots
  - Mirror insertion
  - Setting 850G plunger depth, force limit, limit switches
  - Mirror 3-point mounting
  - Special handling instructions for optics, flex-pivots

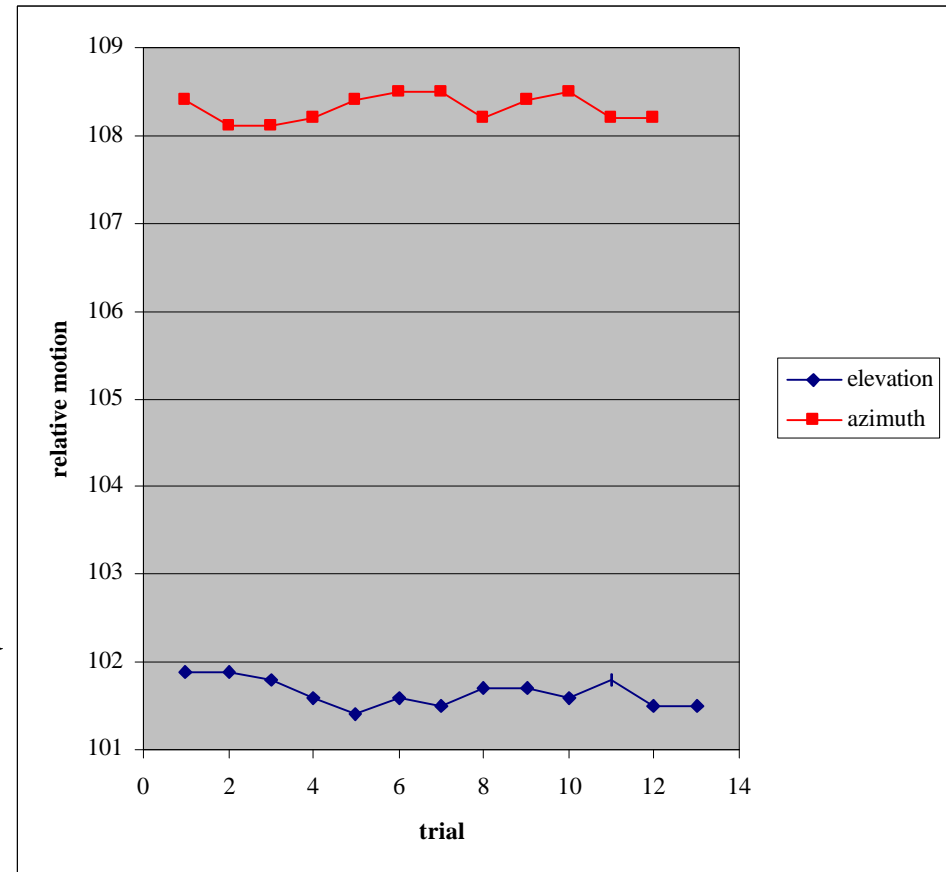
## Performance Data (Representative Mount)

- Values given are lab-tested for mount made from production prints
  - Measured in lab using autocollimator
- Scale factors - 850G encoder
  - 34 counts/arcsec in altitude
  - 89 counts/arcsec in azimuth
- Mounted interferogram already shown
- Resonance frequencies
  - Azimuth: >50 Hz
  - Altitude: >50 Hz



## Performance Data. II (Representative Mount)

- Pointing range (physical)
  - $7.6^\circ$  in altitude
  - 1400 arcsec in azimuth
- Pointing precision
  - Good to  $<1$  arcsec in both altitude and elevation for unidirectional relative moves
  - Bi-directional moves: ‘dead zone’ of  $\sim 0.5$  arcsec for elevation,  $\sim 0.8$  arcsec for azimuth
  - Zero point drift of  $\sim 1$  arcsec seen over a dozen moves



## Checkout of Remaining Optics & Mounts

- Mount to be done:
  - Will be delivered from B&B - 4/27
  - Final assembly / motion control verification - 4/28-5/3
  - Boxing - 5/4, 5/5
- Mirrors ready to ship
- Post-review
  - Shipping
  - Summit delivery
  - Uncrating
  - Placement
  - Mount, actuator, mirror ID assignment upon basement install

# Mirror Location, ID Spreadsheet

- Identifies location of mirrors in GFCS
- Unique IDs for mirrors, actuators, and mounts to be assigned to each station
- Document posted to docushare
  - Two versions, covering Phases 1 and 2+

	INITIAL OPs			FINAL									
	BM0,0 X	BM0,0 Y	BM0,0 Z	BM0,0 X	BM0,0 Y	BM0,0 Z	coordinate status	Mirror Size	Located in lab?	Mount	Mirror ID	Actuator IDs	Mount ID
Name													
JPL-provided Transport Optics													
K1:LDL1	9.477	-0.809	1.463	9.477	-1.063	1.463	final	B	1 B	TBD	TBD	TBD	TBD
K1:LDL2	-10.299	-0.809	0.522	-10.299	-1.063	0.522	final	A	1 LDL	TBD	TBD	TBD	TBD
K1:LDL3	14.330	-0.809	2.152	14.330	-1.063	2.152	final	A	1 A	TBD	TBD	TBD	TBD
K1:LDL4	-10.301	-0.809	0.915	-10.301	-1.063	0.915	final	A	1 LDL	TBD	TBD	TBD	TBD
K1:LDL5P	6.287	-0.809	0.827	6.017	-1.063	0.827	final	C	1 C	TBD	TBD	TBD	TBD
K1:LDL5S	8.958	-0.809	1.003	8.958	-1.063	1.003	final	C	1 C	TBD	TBD	TBD	TBD
K1:M8	-53.118	0.265	1.223	-53.118	0.265	1.223	final	B	0 B	TBD	TBD	TBD	TBD
K1:M9	9.477	0.265	1.463	9.477	0.265	1.463	final	B	1 B	TBD	TBD	TBD	TBD
K2:LDL1	9.943	-0.507	1.463	9.943	-0.809	1.463	final	B	1 B	TBD	TBD	TBD	TBD
K2:LDL2	-10.299	-0.507	0.522	-10.299	-0.809	0.522	final	A	1 LDL	TBD	TBD	TBD	TBD
K2:LDL3	14.330	-0.507	2.152	14.330	-0.809	2.152	final	A	1 A	TBD	TBD	TBD	TBD
K2:LDL4	-10.301	-0.507	0.915	-10.301	-0.809	0.915	final	A	1 LDL	TBD	TBD	TBD	TBD
K2:LDL5P	6.581	-0.507	0.827	6.287	-0.809	0.827	final	C	1 C	TBD	TBD	TBD	TBD
K2:LDL5S	9.229	-0.507	1.003	9.229	-0.809	1.003	final	C	1 C	TBD	TBD	TBD	TBD
K2:M8	31.880	0.265	1.222	31.880	0.265	1.222	final	B	0 B	TBD	TBD	TBD	TBD
K2:M9	9.943	0.265	1.463	9.943	0.265	1.463	final	B	1 B	TBD	TBD	TBD	TBD
sid1:LDL1	10.476	-0.809	1.463	10.705	-0.507	1.463	final	B	1 B	TBD	TBD	TBD	TBD
sid1:M9	10.222	-0.555	1.181	10.451	-0.253	1.181	final	B	1 B	TBD	TBD	TBD	TBD
sid2:LDL1	10.705	-0.507	1.463	10.705	-0.507	1.463	final	B	1 B	TBD	TBD	TBD	TBD
sid2:M9	9.850	-27.620	1.181	9.850	-27.620	1.181	final	B	0 B	TBD	TBD	TBD	TBD

## Shipping Plan. I

- Inventory
  - 38 mirror mounts will be at JPL 4/27
  - 22 mirrors at JPL
  - 24 mirrors on order for TOs and LDL
- 14 mounts & optics to ship to Hawaii 5/5
  - 10 Bs, 4 Cs for Phase 1 install
  - Mirrors to be air shipped in crates
  - Mounts to be air shipped in foam-injected boxes
  - Mirror dust hoods being fabbed separately and will ship 4 weeks later
- 2 LDLs, 2 FDLs to ship to Hawaii 6/5 (??)
  - 4 A, 2 FDL mirrors to ship with carts

## Shipping Plan. II

- 8 mounts & optics to be used at JPL for integration & test prior to Phase 2
  - Sizes: 2 A, 2 B, 4 C
- 16 mounts & optics to ship to summit early '01 in support of Phase 2
  - Mount sizes: 6 A, 6 B, 4 C
  - 4 A mirrors for LDLs as well

## Shipping Details

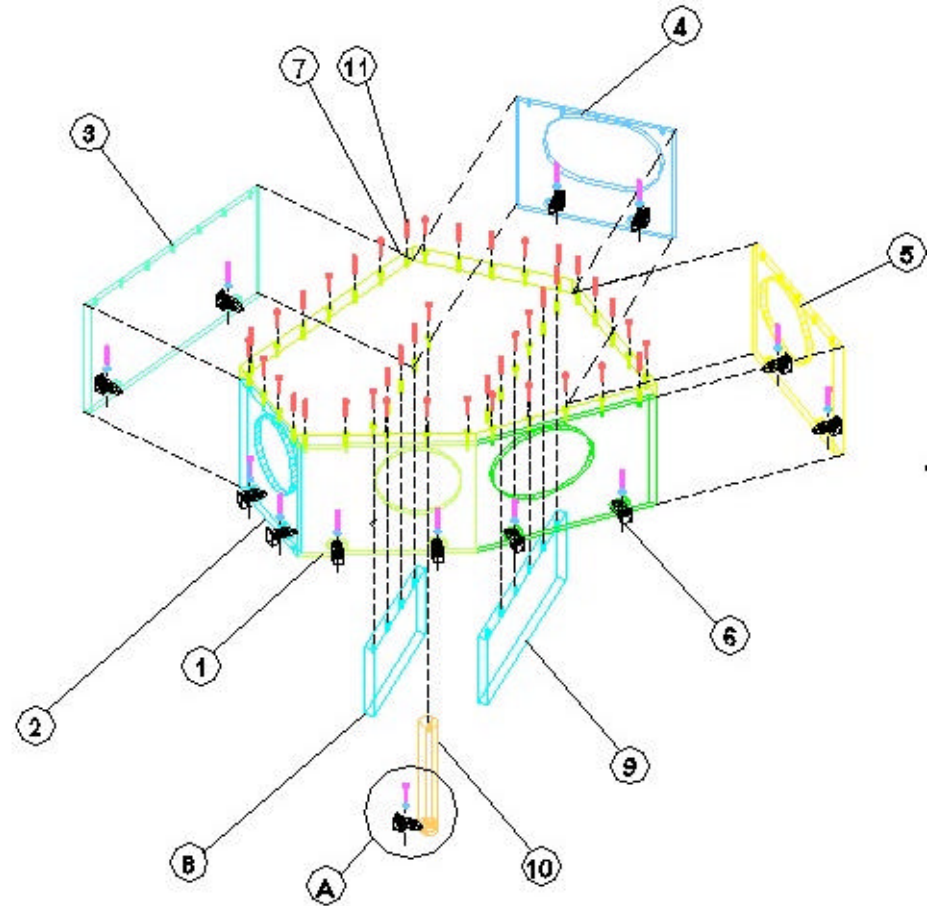
- Packing
  - Mirrors: Already crated in wooden boxes
  - Mounts: To be boxed, foam-injected
- Air shipping to Kona: 5/5
- Delivered to HQ in Waimea: 5/8
- Transported from HQ to summit: 5/9-5/12
- Staging area: Mirror barn 2
  - Mounts, mirrors to be unpacked
  - Basement placement based upon GFCS spreadsheet
- Mount, actuator, mirror ID assignment upon basement install

## Install Plan

- Locate optical elements based upon GFCS coordinates
  - Coordinates posted to docushare
- Align using laser boresight
  - Follow beamtrain in a reverse sense from BCL to M7's using CARA provided boresight laser
  - Tweak element positions based upon FDL, LDL as-builts
  - Final align needs carts/sleds in place
- Test to repeat upon install
  - Pointing verification with autocollimator using EPICS

# Mounting Requirements

- Tables in LDL area
- Bi-level mounting on LDL tables 13, 14
  - Highrises designed by JPL
  - Fab by CARA
- “Tables” 11A, 11B, south tunnel area
  - Pedestals derived from FDL stanchions



## Outstanding Issues

- Coating for 45° incidence mirrors
  - Issues: Reflectance at 0.6μm, 8-14μm, polarization, longevity, maintainability
  - Remedy: Gold, other coatings being explored
- Autoalignment system
  - Issues: Overall design issues
  - Remedy: To be covered in separate review

# Summary

- Performance requirements met

- Range of motion
  - 23 arcmin in azimuth
  - 8° in altitude (for LDL TOs, otherwise 20 arcmin in altitude)
- Incremental moves
  - <1 arcsecond optical
- Surface quality
  - $<\lambda/20$  p-v surface at  $\lambda=633\text{nm}$  for mounted optics
- Mirror coating
  - Denton FSS-99 protected silver

- Documentation

- Inventory, install plan
- Fabrication plans
- Assembly instructions
- Data sheets
- Ordering information
- Mirror placement coordinates
- Shipping plans

- Exceptions

- Tests done on representative mount
- Dust covers ship separately